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ABSTRACT

In an effort to develop a course in materials and processes of industry at Norfolk State College using Barton Herrscher's model of systematic instruction, a group of 12 NASA-Langley Research Center's (NASA-LRC) research engineers and technicians were recruited. The group acted as consultants in validating the content of the course and aided in obtaining useful resources for teaching the course. The practicum was conducted over a full semester, excluding three months of arranging for the team, and involved the NASA group in lecture/demonstrating, student career counseling, obtaining instructional materials for the college's continued use, arranging field trips, discussing course content and evaluation, and broadening the cooperation between Norfolk State College and NASA-Langley Research Center. The practicum resulted in the following outcomes: (1) development of goals and instructional objectives for the first course in materials and processes of industry, (2) updated the instructor's background, (3) provided students with valuable instruction and motivation, (4) increased resources and visual aids for the college, (5) developed greater rapport between Norfolk State College and NASA-LRC, (6) post-assessment, and (7) remediation to overcome shortcomings. (Instructional objectives for a first course in materials and processes of industry are appended, and include 11 topics.) (Author)

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THE CONTENT VALIDATION AND RESOURCE DEVELOPMENT FOR A COURSE IN MATERIALS AND PROCESSES OF INDUSTRY THROUGH THE USE OF NASA EXPERTS AT NORFOLK STATE COLLEGE

James A. Jacobs

Final Report
of a
Cooperative Venture
between
N.A.S.A. Langley Research Center
and
Mechanical Design Technology
Norfolk State College

December, 1975

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ABSTRACT

The Content, Validation and Resource Development of a Course in Materials and Processes of Industry through the Use of NASA Experts at Norfolk State College

In an effort to develop a course in materials and processes of industry at Norfolk State College using Barton Herrscher's model of systematic instruction, a group of twelve NASA-Langley Research Center's research engineers and technicians were recruited. The group acted as consultants in validating the content of the course and aided in obtaining useful resources for teaching the course. The practicum was conducted over a full semester, excluding three months of arranging for the team, and involved the NASA group in lecture/demonstrating, student career counseling, obtaining instructional materials for the college's continued use, arranging field trips, discussing course content and evaluation, and broadening the cooperation between Norfolk State College and NASA-Langley Research Center.

The practicum resulted in the following outcomes: (1) development of goals and instructional objectives for the first course in materials and processes of industry, (2) updated the instructor's background, (3) provided students with valuable instruction and motivation, (4) increased resources and visual aids for the college, (5) developed greater rapport between Norfolk State College

(often including the design of his own activity), (6) post-assessment, and (7) remediation to overcome shortcomings. Additionally, attachments were made to the cluster modules that aided in orienting the student to the learning alternatives and supplies resources and references for accomplishing the module cluster objectives.

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INTRODUCTION

The industrial technology curricula at Norfolk State College (NSC) have a requirement for all students to complete a course in materials and processes of industry as do most colleges that offer engineering or industrial technology programs. The course is intended to orient the students to a wide range of engineering materials and to the methods of processing the materials for product manufacturing. This writer has taught the course for six years at Thomas Nelson Community College and Norfolk State College. While endeavoring to maintain an interesting and current course, he has been concerned with the validity of the subject matter and desired to improve the instructional techniques. This concern coupled with a desire to increase student motivation prompted a successful effort to gain assistance from researchers and technicians at NASA's Langley Research Center (NASA-LRC) in Hampton, Virginia. NASA-LRC is recognized as one of the world's finest materials research and development facilities with internationally known researchers and technicians.

BACKGROUND AND SIGNIFICANCE

> Most students (perhaps more than 90 percent) can master what we have to teach them, and it is the task of instruction to find the means which will enable them to master the subject under consideration.[1]

Bloom's theory of mastery has gained wide support in recent years. It has guided educators to seek methods of instruction that will allow more students to obtain mastery instead of settling for the normal curve as the limiting factor in student achievement. Considerable research has been devoted to developing systematic approaches to instruction which will foster maximum student learning.

Systems Approach

Ralph Tyler began developing the systematic approach to instruction around 1935. His principles were utilized by the U. S. Armed Forces prior to the recent acceptance by public education. The systems approach developed from the engineering systems methods developed by engineers, psychologists, systems and procedures designers. This concept provides means to analyze instructional problems and to formulate logical procedures for the solution of

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[1]Benjamin S. Bloom, J. Thomas Hastings, and George F. Madaus, Handbook on Formative and Summative Evaluation of Student Learning (New York: McGraw-Hill, 1971), p. 43.

the problems. Tyler proposed the following major components for a systems approach: (1) statement of objectives, (2) standards to judge the objective, (3) the necessary activities to achieve the objectives, and (4) the final evaluation and revision procedures.[2]

Since Tyler's groundwork, there have been numerous models developed for the systems approach to instruction all of which embrace Tyler's four basic components. Each component deserves considerable effort for the proper development of a systematic instructional program, and discussion of each component is beyond the scope of this practicum report; however, the writings of Kemp[3], Popham[4], Mager[5], Bloom[6], Herrscher and Roueche[7], and

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[2]John E. Roueche, A Modest Proposal: Students Can Learn (San Francisco: Josey-Bass, 1972), p. 47.

[3]Jerrold E. Kemp, Instructional Design (Belmont, Calif.: Fearon Publishers, 1971).

[4]W. James Popham and Eva L. Baker, Systematic Instruction Englewood Cliffs, N.J.: Prentice Hall, 1970), and Criterion-Referenced Instruction (Belmont, Calif.: Fearon, 1973).

[5]Robert F. Mager, Developing Vocational Instruction, 1967, Goal Analysis, 1972, Preparing Instructional Objectives, 1962, Analyzing Performance Problems, 1970, Developing Attitudes Toward Learning, 1968, and Measuring Instructional Intent, 1973, (Belmont, Calif.:Fearon Publishers).

[6]Benjamin S. Bloom and others, Handbook on Formative and Summative Evaluation of Student Learning (New York: McGraw-Hill, 1971) and Taxonomy of Educational Objectives: Handbooks I:Cognitive Domain and II Affective Domain (New York: David McKay, 1956 & 1964).

[7]John E. Roueche and Barton R. Herrscher, Toward Instructional Accountability (Palo Alto, Calif.: Westinghouse Learning Corp.,1973).

others[8] served as sources of direction in designing and conducting this practicum.

Herrscher developed an operational instructional system model by synthesizing the works of Ralph Tyler, W. James Popham, Bela Banathy, and Jerrold Kemp.[9] His model shown in Figure 1 has been selected as the model to use in developing a course in materials and processes of industry at Norfolk State College.

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[8]Lawrence P. Grayson and Joseph M. Biedenback, eds. Individualized Instruction in Engineering Education (Washington: American Society for Engineering Education, 1974, and "Special Effective Teaching Issue" of Engineering Education, March, 1974.

[9]Barton R. Herrscher, Implementing Individualized Instruction (Houston: ArChem Company Publishers, 1971), p. 4.

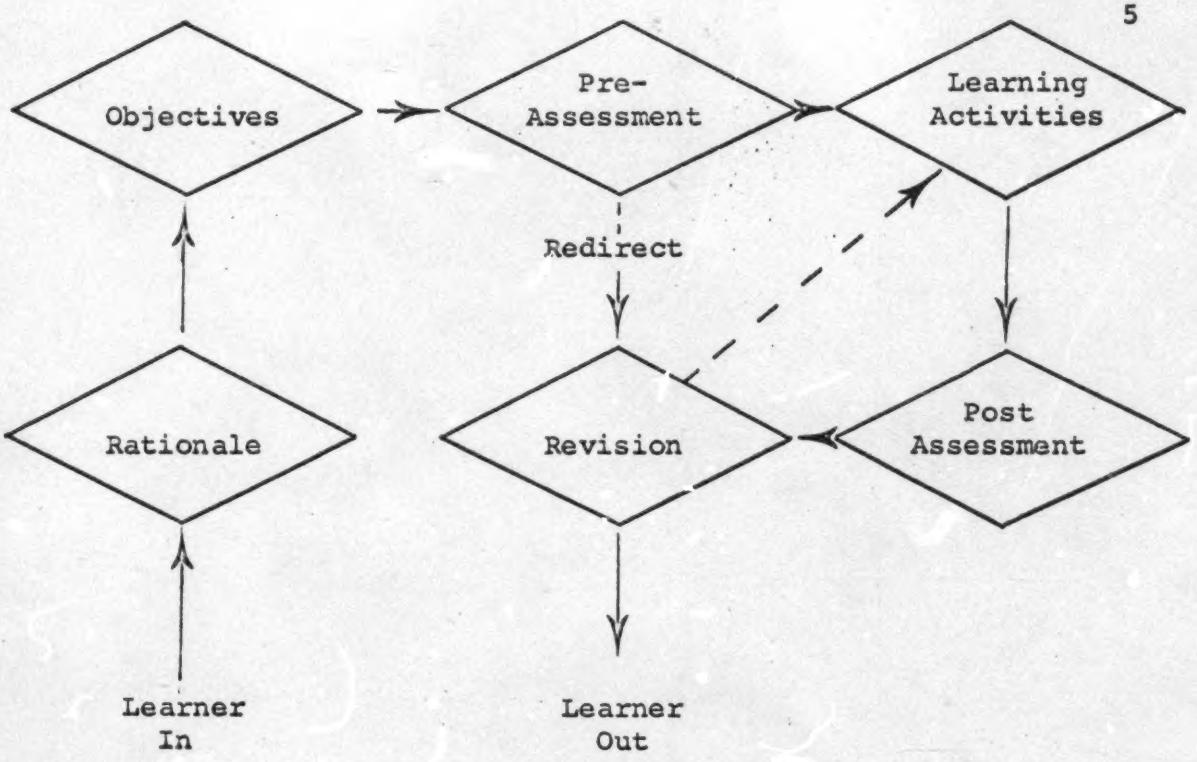

FIGURE 1 An Instructional System

This model was selected because it is aimed at providing for individual differences among students and seeks to develop instruction based on criterion reference evaluation that is aimed at increasing each student's chances for subject mastery rather than a system that succumbs to the "normal curve". It is the philosophy of Norfolk State College and this instructor that the college must develop each student to his or her potential despite the academic deficiencies that he or she may bring to the college.

Developing Objectives

All of the models for the systems approach to instruction place considerable emphasis on the objectives around which the systems develop. In technology curricula as probably with all occupational curricula, it is possible to determine the specific objectives for the given technical speciality. The literature presents a number of techniques for analyzing the educational needs of occupations. Fryklund emphasizes the use of a systematized inventory of those tasks found in a given occupation as his book outlines the procedures for educators to use in their study of industry in order to determine curricula content.[10] Popham reminds us that the final decisions on objectives are subjective because there are so many possibilities; however, it is wise to look at the three major sources specified by Ralph Tyler, i.e., the learner, the society, and the subject matter.[11] Determining the dictates of the society (in our cases the industrial setting in which our students will be placed) and the subject matter is quite challenging due to the changing nature of technical fields. Further complications arise from the numerous levels of training required

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[10]Verne C. Fryklund, Occupational Analysis Techniques and Procedures (New York: Bruce Publishing, 1970).

[11]Popham, op. cit., pp. 45-62.

in a field. Baldwin examines these levels along with the domains (cognitive, affective, and psychomotor) in which the objectives should be classified.[12] Textbooks and curricula guides offer a good source to begin developing objectives. As previously mentioned, occupational analysis is essential as are the use of lay advisory committees which should consist of people working in the technical field under study; the literature places great emphasis on these sources.[13]

This researcher has employed the aforementioned strategies for developing course objectives including a very thorough study of the mechanical design technology field. This study was first

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[12]Thomas S. Baldwin, "Evaluation of Learning in Industrial Education," Handbook on Formative and Summative Evaluation of Student Learning, Bloom, op. cit., pp. 857-869.

[13]Criteria for Technical Education-A Suggested Guide (Washington, D. C.: U.S.O.E. Bulletin E-80056, 1968), Melvin L. Barlow, ed., Vocational Education-The Sixty-Fourth Yearbook of The National Society for the Study of Education (Chicago: University of Chicago Press, 1965, Samuel M. Burt, Industry and Vocational Technical Education: A Study of Industry Education-Advisory Committee (New York:McGraw-Hill, 1967), Henry Leonard Carlson, "Functions and Activities of Lay Advisory Committees for Selected Junior College Vocational Programs", University of California, Los Angeles, Unpublished Doctorate Dissertation, 1967, and Milo P. Johnson and Albert J. Grafsky, Jr., Accountability-Evaluation for Occupational Programs (Chicago: American Technical Society, 1973).

conducted in 1969 and since then continually updated.[14] Additionally, other surveys have been consulted including an extensive survey conducted in the State of Washington.[15] However, these sources still offer rather general guides to the educator because it is impractical to perform a complete analysis of every technical course in a given curriculum because of the time and manpower required. Consequently, the major task of developing course objectives is on the instructor who is expected to possess the proper technical background. In the case of the materials and processes of industry course at NSC, the subject is very broad and changes more rapidly than textbooks, so it was considered desirable to consult experts in the field. The opportunity to have NASA-LRC experts available for a full semester offered a unique and valuable chance to develop sound educational objectives.

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[14] James A. Jacobs, "An Analysis of Occupational Requirements of Selected Organizations on the Virginia Peninsula Employing Drafting and Design Technicians", (unpublished masters research project, College of William and Mary, 1969).

[15] "Mechanical Engineering Technology: Performance Specifications and Training Objectives for the Technician" (Olympia, Washington: State of Washington Coordinating Council for Occupational Education, 1970).

Writing Objectives

There has been a plethora of writings in the last ten years or so on objectives with an emphasis on behavioral, performance, or measurable objectives. Cohen has done considerable work with regard to objectives for college teaching and summarizes the essence of performance objectives --

> . . . it must specify a study action or product of such action, it must state the conditions under which the performance will occur, and it must establish a minimum performance criterion, a standard.[16]

His book, Objectives for College Courses, offers pro and con discussions on behavioral objectives and supplies a programmed text on how to write them.[17] The ERIC Clearinghouse for Junior Colleges plus the Clearinghouse on Career Education (formerly Vocational-Technical Education) have developed series of courses objectives that can serve as a guide or in some cases may exactly

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[16] Arthur M. Cohen, "Defining Instructional Objectives," Koueche and Herrscher, op. cit., p. 57.

[17] Arthur M. Cohen, Objectives for College Courses (Beverly Hills, California: Glencoe Press, 1970).

fit one's own course. A review of the Junior College list[18] and a search of ERIC Abstracts failed to turn up a list of course objectives for a course in materials and processes of industry.

Using Bloom's, et. al., taxonomy is an involved process and one has to question the practicality of the average professor tackling such a thorough analysis of each course he teaches, especially if he teaches in technology curricula. The techniques previously mentioned by Baldwin involve writing appropriate objectives at all levels (affective, cognitive, and psychomotor) to insure that (1) the entire scope of a field is covered and (2) sufficient criteria have been established to measure the student's learning.[19] To avoid criticism of those objectives developed by a professor, it is suggested that advisory committees verify them.[20] This writer has recently completed a practicum on a scheme to insure the validity of objectives as they are developed.[21]

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[18] A Brief Review of Instructional Objectives for Junior College Courses (University of California: The ERIC Clearinghouse for Junior Colleges, June, 1973).

[19] Baldwin, loc. cit.

[20] Johnson and Grafsky, op. cit., p. 23.

[21] James A. Jacobs, "A Scheme to Employ Management by Objectives to Facilitate Instruction for the Division of Industrial Education and Technology at Norfolk State College" (unpublished practicum, Nova University, 1974), pp. 47-53.

Measuring the Objectives

"Grading is a largely subjective, extremely imprecise operation which unfortunately, most teachers must carry out."[22] However, properly stated objectives should convey those changes which are expected in the student and when broken into appropriate learning units can readily serve as the guide to the writing of test questions or activities for formative and summative evaluation of student learning.[23] Mager offers a gem of a fable along with programmed text and a flow chart for arriving at test items that match overt action of objectives; he instructs ... "Ask him simply and directly to do the thing you are after."[24]

Basic to the question of testing is the philosophy of education of an instructor. If it is the intent to show differences in students and act as the human caliper to selectively fit everyone into their place in the normal curve, then item construction should emphasize variance, but when the aim is to strive toward the maximum of students achieving mastery then test items must be designed

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[22]Popham (1973) op. cit., p. 46.

[23]Bloom, et. al., pp. 20-67.

[24]Robert F. Mager, Measuring Instructional Intent (Belmont, California: Fearon, 1973), Preface, p. 93.

to precisely match the criterion behavior.[25] This instructor has had no problems with accepting the criterion-referenced measurements because it not only seemed the only valid means of determining technical competence, but is consistent with the democratic principles espoused in this country.

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[25] W. James Popham and T. R. Husek, "Implications of Criterion Referenced Measurements," Journal of Educational Measurement, Vol. 6, No. 1 (Spring, 1969), pp. 1-9.

PROCEDURES

Past experience in the use of technical specialists as guest lecturers has proven a valuable assistance in a course to (1) motivate students, (2) develop relevant objectives, (3) update instructor's background, (4) add to sources of technical data, (5) collect instructional materials, and (6) improve rapport with agencies that employ graduates. To gain such benefits assistance from NASA-LRC was sought to teach a course in materials and processes of industry at Norfolk State College. Committed to furthering education and with an interest in increasing the opportunities for minorities to enter the engineering technology careers, NASA-LRC agreed, after several months of discussions and exchange visitations, to supply a team of research engineers and technicians to act as consultants and lecturers for the first course in materials and processes of manufacturing at Norfolk State College, a predominately black institution.

With the upper NASA-LRC management's go-ahead, an organizational meeting was held with various levels of supervisors from the areas of technical specialty that the course involved. This group was presented copies of the previously used course syllabus with the request that they locate researchers and technicians to act as consultants in revising the course and conducting the

appropriate classes during the semester. Shortly thereafter, the following group of researching engineers and technicians was assembled:

Samuel J. Scott (aeronautical engineer) - Introduction to Materials and Processes

James T. Davis (mechanical/structural technician) - Properties of Materials

Bland A. Stein (metallurgical engineer) - Nature of Metals and Alloys

Thomas T. Bales (metallurgical engineer) - Production and Properties of Common Metals. Foundry

Wayne A. Wright (heat treatment technician) - Heat Treatment

Robert M. Baucom (mechanical/polymer engineer) - Non-Metallic Materials

George H. Veneris (metal spinning technician) - Hot-working Metals

John H. Belveal (fabricating technician) - Welding Principles of Design

James W. Haas (welding technician) - Gas and Electric Welding

Boyd H. Wilfong (welding technician) - Newer and Exotic Welding and Brazing

Harry B. Slade (fabricating technician) - Fasteners

Joseph V. Boyle, Jr. (materials technician) - Group Liaison

The group represented an outstanding blend of backgrounds that not only offered expertise of internationally renoun, but also was varied as to career preparation and ascent up the career ladder.

To illustrate, Mr. Scott, as a black aeronautical engineer, served as a model for the mostly black engineering technology students in the class to respect. He not only taught classes, but held a special guidance session that focused on subject matter and career orientation. Tom Bales conducted six sessions and in the course of his instruction, related his career preparation. This included working in a shipyard foundry apprenticeship until he decided that type of manual work would not be his life's work, whereupon he pursued mechanical engineering beyond his masters degree. Robert Baucom went to great efforts to assemble unique demonstrations, collect and disseminate supplementary technical data, and promote maximum involvement of the class. The efforts of these three men are typical of this NASA-LRC group's fantastic spirit of concern for presenting the students with the best possible instruction and advice. There were other excellent experiences in addition to numerous hours given for after-class help sessions. An all day field trip to the Langley Research Center was very broadening to the students and allowed them to see a research facility (the first time for most). Films, engineering models, engineering projects, and other audio visual aids were used frequently. The aids were far beyond that which the average college professor would have access. Because of the

interest generated on the field trip, a special three hour seminar for the entire college was conducted on nondestruction testing (NDT) with demonstrations on radiographic, sonic, ultrasonic visual, and other NDT techniques.

At the end of the course a student questionnaire was used to ascertain the student's view of the manner in which the course was taught and to seek their suggestions for means of improving the course.

Results

This instructor had the responsibility of two sections of materials and processes of industry while this practicum was being carried out. The NASA-LRC team was used on Monday and Wednesday afternoons and this instructor taught the other section by himself on the mornings of Tuesday and Thursday. Consequently, it was possible to obtain immediate results from the NASA-LRC expertise. In accordance with the practicum proposal's fourth objective (to develop a methodology in the instructional system so that the course includes all of the necessary facets of an effective instructional system and reflects the standards of "state-of-the-art" technology), there was opportunity to make adjustments on a daily basis to improve instruction to the group not receiving NASA-LRC instruction.

Accomplishment of the first, second and third objectives was achieved over the semester. Those objectives follow: First, develop the most current and relevant objectives on materials and processes. Second, use the NASA-LRC jury of experts to validate the course objectives insuring adequate comprehensiveness to meet the standards of the technical specialities involved, preventing obvious omissions or unnecessary inclusions in overall content, and providing an appropriate level of difficulty for the target student population. Third, to develop and validate test questions that are keyed to course objectives and would thus insure learning experiences which measure the attainment of the objectives at appropriate levels in Bloom's Taxonomy of Objectives. The objectives listed by topics are shown in the Appendix and are results of the first, second, and third objectives. In addition to meeting those three objectives while having the students receiving instruction, each NASA-LRC consultant was able to assist with the following:

1. Obtaining of resources: films, references, etc.
2. Promoting affiliations with professional societies (e.g. American Society of Metals)
3. Securing objects for future demonstrations

The fifth objective was long term: to develop lasting relationships with NASA-LRC which will avail to the college, especially the Mechanical Design Technology program, those available NASA-LRC personnel and material resources. This objective was developed beyond all expectations. Not only did each consultant extend his continuing availability but other NASA-LRC personnel were contacted. For example, the Education Chairman of the local American Society of Metals through Mr. Stein's recommendation secured on permanent loan a film and sets of overhead transparencies and demonstration objects. It was possible to borrow an eight thousand dollar milling machine from NASA-LRC with a commitment for use of other equipment that might become available. Members of the Division of Industrial Education and Technology at NSC were introduced to NASA-LRC personnel from a number of technical areas so that they could pursue further interagency cooperation. An example of success in that respect came when a NASA-LRC technician was placed on a one-year loan to NSC through the Intergovernmental Personnel Loan Act of 1970. This federal law provides for exchange of governmental employees in order to loan expertise from one government (federal, state, or local) agency to another.

In summary, this practicum, while requiring many more hours of coordination than anticipated, proved to be a valuable venture

that increased this practioner's background on materials and processes of industry, produced a relevant and interesting course, and developed a new cooperation between NASA-LRC and NSC which will be beneficial to both agencies. Student reaction as revealed by the questionnaire was favorable. As expected, the students rated the class taught by the NASA-LRC team higher in each category than the class taught by this instructor alone.

Recommendations

The review of the literature found an emphasis on involving lay advisory groups for occupational/technical education. This practicum provided for maximum participation of a group of experts in one course in materials and processes of industry. While this level of assistance will normally not be available to a college, it is highly recommended that considerable effort be extended to obtain cooperation from knowledgeable lay people for technical curricula. The cooperation, as revealed in the literature and from this practicum, provided the college with current information on "state-of-the-art" theory and practice while adding valuable information to the faculty and instructional resources to the college.

Norfolk State College should broaden the cooperation with NASA-LRC in all ways possible. Not only will this offer the

college valuable resources, but it will promote placement of graduating students with the agency and can provide benefits similar to those obtained by this practicum.

The list of objectives for a first course in materials and processes of industry (Appendix) reflects the ideas of authors in the field, six years of teaching the course by this instructor, and recommendations from a team of NASA-LRC research engineers and technicians who are recognized authorities. Faculty who teach a similar course should find the objectives useful as reference.

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APPENDIX

Instructional Objectives for A First Course in Materials and Processes of Industry

Goals:

As a result of this course the successful student will be able to do the following:

1. Identify the elementary factors that influence operational procedures and dictate design consideration of manufacturing industry.

2. Recount the properties of metals and associate the properties with the fabrication characteristics of metallics.

3. Identify casting and molding processes and recount basic selection and design considerations required by these processes.

4. Identify forging and hot working operations and recount basic selection and design considerations required by these processes.

5. Identify major weldings, brazing, soldering, hard surfacing, and torch cutting processes and recount basic selection and design consideration required by these processes.

6. Specify basic factors that would lead to the selection or rejection of plastics in product design.

7. Differentiate between methods of mechanical and adhesive joining processes with implications for product design.

Specific Topic Objectives:

Because this course is taught without an accompanying laboratory, the conditions under which the student performs are

strictly classroom and standards of performance are those set by the text and reference material. Students will be evaluated on paper and pen examinations using those definitions and concepts covered by the text, lecture/demonstration and supporting audio visuals.

Topic #1 - Introduction

- Recount the course scope, basic goals, procedures, and evaluation techniques plus the student's responsibility for the course
- Develop an awareness of the general nature of the manufacturing industry
- Explain in your own words the value of a knowledge of materials and processes of industry with regard to your career aspirations
- Explain the function of standardization agencies and professional societies; list three such organizations
- List the five classes of solid materials used in engineering
- List at least five processes used on solid materials
- Briefly explain in your own words the importance of safety to a technician

Topic #2 - Properties of Materials

Given a list of the following words, match them to the appropriate definitions:

physical properties	yield point
chemical properties	stress
mechanical properties	fatigue
hardness-brittleness	strain
plasticity-ductility	modulus of elasticity
toughness	shear
malleability	creep
strength	tension
elongation	compression

- Draw a typical stress-strain curve, label the strain and stress axes, elastic limit, yield point, ultimate load, breaking point, and explain the purpose of the stress-strain diagram

- Given the following destructive tests, match them to the proper mechanical properties which they measure:

  hardness test (Rockwell, Vickers, Brinell)
  tension test
  torsion test
  impact test
  fatigue test

- Specify the units for measuring (a) stress, (b) strain

Topic #3 - Nature of Metals

- List the common crystal structures of metals

- Define the term alloy

- Sketch a typical cooling curve of a pure curve and an alloy

- Using reference material, match the following terms to their definitions:

grain	allotropy
crystal	solid solution
phase	equilibrium diagram

- Using references, sketch the microscopic grain structure of any selected composition in a given phase diagram

Topic #4 - Heat Treatment of Metals

- Using references, briefly outline the process steps required to harden steel

- Explain the results of increasing carbon in steel

- Match the following terms to their definitions:

hardening	surface hardening
annealing	normalizing
tempering	

Topic #5 - Production and Properties of Metals

- List the raw materials used in the production of iron

- Using a reference, match the various types of furnaces to their major uses

- Identify low, medium, and high carbon, and cast iron by its percentage of carbon

- Identify the function of various alloys used in steel

- Determine the make up of a given steel by its AISI-SAE designation

- Match the common nonferrous metals to their major advantages and production methods. Select designated ferrous and nonferrous metals to fit given applications

Topic #6 - Non-Metallic Materials

- Develop an appreciation for the growing importance of nonmetallic materials as engineering materials

- Define the following terms and given an example of each:

plastic	thermoplastic
polymer	thermoset
ceramic	elastomer

- Diagram the molecular structure of (a) polyethylene and (b) polyvinyl chloride

- Match the following terms to their definitions or applications:

crosslinking	injection molding
catalyst	reinforcing
blow molding	
casting	

- Given specific applications in which plastics can be used,

select the plastic to best fit the given applications

Topic #7 - Metal Casting

- Match the following terms to their definitions or functions:

draft	cores
fillet	sprue
round	riser
patterns	

- Match the following casting processes to specific design criteria:

green sand casting	investment casting
shell molding	permanent mold casting
die casting	centrifugal casting
plaster mold casting	

Topic #8 - Hot-Working Metal

- Describe the effects of hot working metal

- Match the following hot-working processes to specific design criteria:

forging	spinning
rolling	pipe and tubing manufacturing
extrusion	

- List typical products of hot-working

- List secondary operations used for hot-worked products

Topic #9 - Thermal Bonding

- Match the following thermal bonding techniques to their definitions or applications:

oxyacetylene welding	resistance welding
electric arc welding	brazing
inert gas welding (MIG & TIG)	soldering
electron-beam welding	surface coating
ultrasonic welding	flame cutting

- Describe the major thermal effects of welding

- Recount the approximate temperatures of the major thermal bonding methods

- List five common design considerations required for welding

- Construct basic weld symbols to match given weld joints

Topic #10 - Adhesive Bonding

- List three common adhesives used in engineering applications

- List three common design considerations required for adhesive bonding

Topic #11 - Mechanical Fasteners

- Identify common mechanical fasteners

- List three common design considerations required for use of mechanical fasteners

- Given a situation in which components must be joined, recount the advantage and disadvantage of thermal bonding, adhesive bonding, and mechanical fasteners and select the joining technique best for the given situation.